Measurement of Gluino-Sbottom Mass Splitting

W.-M. Yao
Lawrence Berkeley Natation Laboratory
Berkeley, CA 94720

ABSTRACT

We have developed a technique to measure the gluino and sbottom mass splitting using the D^* trick by assuming a value of $M_{\chi_1^0}$. The expected precisions are dominated by systematics and can be reached at ± 2 GeV/c^2 on the ΔM and ± 5 GeV/c^2 on the sbottom mass at NLC comparison point. The same technique can be applied to measure other SUSY particle mass.

I. INTRODUCTION

Several studies in the past demonstrated that the LHC is an excellent machine to discover SUSY particles up to a mass of about 2 TeV[1, 2, 3, 4]. However, there is no existing prove that most of SUSY particle masses and branching ratios could be precisely determined at the LHC after their discovery because of missing the lightest supersymmetric particle (LSP) in the event. This note is an attempt to understand the experimental feasibility of precision measurement of gluino-sbottom mass splitting using partial reconstruction technique, which is similar to $D^* \to D^0\pi$ trick often used in e^+e^- mechine. As an example, we are going to demonstrate the technique using SUSY events generated at one special point in SUGRA parameter space, so called "NLC comparison point"[5], where most of SUSY particles are below 400 GeV/c^2 and copiously produced at the LHC with a cross section of 1.3 μb.

II. THE ANALYSIS

We have used the Monte Carlo events generated with ISASUSY and ISAJET, version 7.20 [6] by F. Paige. A detector toy simulation package is included in ISAJET which contains hadronic and electromagnetic resolution smearing. The signal sample is SUSY production at NLC comparison point which predicts the gluino ($\tilde{g}$) mass of 298 GeV/c^2 and sbottom ($\tilde{b_1}$) mass of 278 GeV/c^2. The decay branching ratios are:

- $\mathrm{Br}(\tilde{g} \to \tilde{b_1} b) = 88\%$
- $\mathrm{Br}(\tilde{b_1} \to \chi_2^0 b) = 86\%$
- $\mathrm{Br}(\chi_2^0 \to \chi_1^0(e^+e^-, \mu^+\mu^-)) = 32\%$,

where the χ_2^0, χ_1^0 are the two lightest neutralinos with masses of 98 GeV/c^2 and 44 GeV/c^2. Throughout this analysis we are going to assume that the masses of χ_2^0 and χ_1^0 have been measured somewhere else[7]. The background samples we consider are Standard Model top production, W+jets and QCD. Both signal and background events are normalized to $10 fb^{-1}$.

A. Event Selection Criteria

In order to reduce the Standard Model backgrounds, we apply the following selection criteria:

- Electrons: $P_t > 7$ GeV/c $|\eta| < 2.5$
- Muons: $P_t > 5$ GeV/c and $|\eta| < 2.5$
- At least one lepton above 20 GeV/c to satisfy the trigger requirement.
- At least two opposite sign and same flavor isolated leptons.
- b jets: $E_t > 10$ GeV and $|\eta| < 2.5$ (a tag efficiency of 50%/per bjet and a mistage rate of 0.05%/per jet).
- At least two identified b's
- Missing Et above 20 GeV

The total acceptance of SUSY events is about 2.6% including decay branching ratios. The dominant background contribution is due to top production. The distribution of invariant mass of dilepton pairs is shown in Figure 1, for both signal and background. A signal to background ratio of 35 is apparent.

B. Partial Reconstruction Technique

As mentioned above, the gluino ($\tilde{g}$) and sbottom ($\tilde{b_1}$) are reconstructed through the following decay chain:

$$\tilde{g} \to \tilde{b_1} b_s \to \chi_2^0 b_h b_s \to \chi_1^0(l^+l^-) b_h b_s \tag{1}$$

where b_s, b_h note the soft and hard bjet from $\tilde{g}$ and $\tilde{b_1}$ decay, respectively. We select the events with the dilepton invariant mass near endpoint of $M_{\chi_2^0} - M_{\chi_1^0}$ between 48.0 to 54.0 GeV/c^2 in which the χ_1^0 and l^+l^- are at rest in the χ_2^0 center mass system (CMS). By measuring the dilepton pair momentum in the Lab frame, the momentum of χ_2^0 and χ_1^0(LSP) can be reconstructed in the lab frame using the following relations.

$$\vec{P}_{\chi_1^0} = \left(\frac{M_{\chi_1^0}}{M_{l^+l^-}}\right) \cdot \vec{P}_{l^+l^-} \tag{2}$$

$$\vec{P}_{\chi_2^0} = \left(1 + \frac{M_{\chi_1^0}}{M_{l^+l^-}}\right) \cdot \vec{P}_{l^+l^-} \tag{3}$$

Then, we combine the χ_2^0 with any b jet in the event to reconstruct the $\tilde{b_1}$ and combine another b jet to reconstruct the $\tilde{g}$. The $\tilde{g}$ and $\tilde{b_1}$ mass splitting can be measured by fitting the distribution of mass difference $\Delta M = M_{\tilde{b}_1 b_s} - M_{\tilde{b}_1}$.

C. Results

A scatter plot of $M_{\tilde{b}_1}$ and ΔM is shown in Figure 2, as well as the projections of $M_{\tilde{b}_1}$ and ΔM by requiring $\Delta M < 30$ GeV/c^2 and $220 < M_{\tilde{g}} < 300$ GeV/c^2. There are about 6000 reconstructed gluino and sbottom events in this channel, which allow us to measure the ΔM and $M_{\tilde{g}}$ precisely. We fit the ΔM distributions using 3th order Chebyshev Polynomial function for the background shape and a Gaussian for the signal shape. The fitted mean value is $\Delta M = 20.5 \pm 1.$ GeV/c^2, in good agreement with the expectation of 20 GeV/c^2.

We have studied the uncertainty due to the assumption of χ_1^0 mass by holding the end point of $M_{\chi_2^0} - M_{\chi_1^0}$ fix and varying the χ_1^0 mass by ± 20GeV/c^2. As we expected, the ΔM is insensitive to the choice of $M_{\chi_1^0}$ and $M_{\tilde{b}_1} = M_{\tilde{b}_1}^{true} + 1.5 \cdot (M_{\chi_1^0} - M_{\chi_1^0}^{true})$.

III. CONCLUSION

We have developed a technique to measure the gluino and sbottom mass splitting using the D^* trick by assuming a value of $M_{\chi_1^0}$. The expected precisions are dominated by systematics and can be reached at ± 2 GeV/c^2 on the ΔM and ± 5 GeV/c^2 on the sbottom mass at NLC comparison point. The same technique can be applied to measure other SUSY particle mass.

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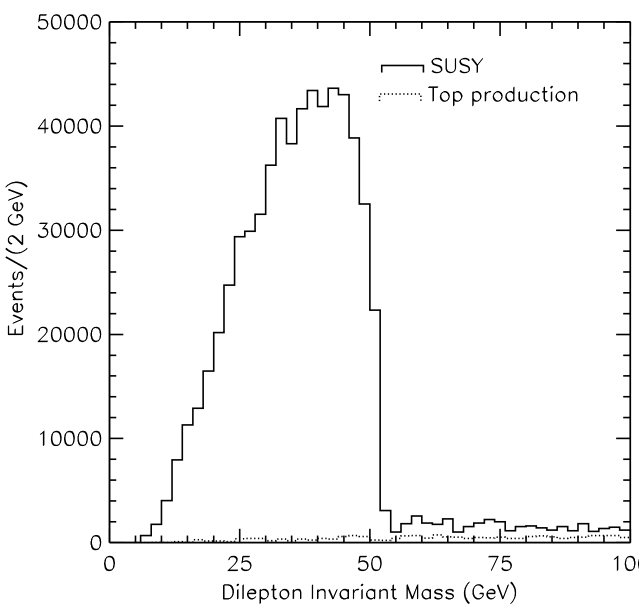

Figure 1: The invariant mass distribution from SUSY and top production, normalized to 10 fb^{-1} LHC data.

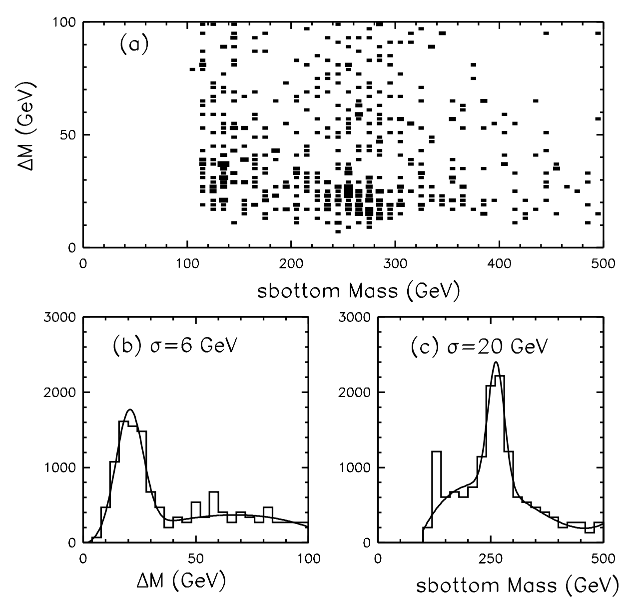

Figure 2: A scatter plot and projections of sbottom mass and mass difference between gluino and sbottom.